PATENT SPECIFICATION

(11) 1291235

DRAWINGS ATTACHED

1291235

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By a direction given under Section 17(1) of the Patents Act 1949 this application proceeded in the name of THE SECRETARY OF STATE FOR DEFENCE, London.

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engine.

It is frequently necessary to provide a fluid flow machine with one or more struts which extends across an annular duct of the machine. Such a strut, however, may produce a non-uniform pressure distribution around the annular duct which can, for example, cause substantial stresses to be imparted to any rotor blades mounted in the duct and upstream of the strut.

According to the present invention, there is provided a fluid flow machine provided with an annular duct having therein a vane assembly comprising a row of angularly spaced-apart stator vanes and at least one strut which extends across the duct and which has at least a leading surface having a leading edge and a trailing edge, the stator vanes on opposite sides of the leading surface of the or each strut being axially staggered, said leading surface being, in operation, substantially parallel to the direction of flow thereover and said vane assembly being such that a substantially uniform pressure distribution is formed upstream thereof.

Preferably the or each strut and the stator vanes are helically arranged and form one substantially complete helical turn. The strut, or at least one of the struts may be disposed between the most upstream and the most downstream stator vane of the said substantially complete helical turn.

In one embodiment said blade assembly includes a respective wall member which with the or each strut defines a duct portion, the stator vanes in said duct portion being helically arranged, the most downstream stator vane being adjacent said leading surface. Thus

assembly includes a second row of angularly spaced-apart stator vanes disposed downstream of the first-mentioned row, the or each strut extending between said rows, said vane assembly being such that said trailing edge is disposed between said rows and the or each strut also has a trailing surface substantially downstream of said second second row, said trailing surface being substantially parallel to the direction of flow thereover. Thus the annular duct may be the main flow duct of a gas turbine engine, the or each strut forming part of bearing support structure which supports a main shaft of the engine from the engine casing, the said main shaft being disposed radially inwardly of the annular duct.

The invention is illustrated, merely by way of example, in the accompanying diagrammatic drawings, in which:—

Figure 1 shows a gas turbine front fan engine in accordance with the present invention,

Figure 2 is a broken-away view on a larger scale of part of the engine of Figure 1,

Figure 3 is a schematic plan view of the embodiment of Figures 1 and 2,

Figure 4 is a broken away sectional view of another gas turbine engine in accordance with the present invention,

Figure 5 is a developed part view looking in the direction of the arrow 5 of Figure 4, and

Figure 6 is a developed part view of another gas turbine engine according to the present invention.

In Figure 1 there is shown a front fan gas turbine engine 10 having an engine casing 11 within which are mounted a compressor,

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(54) FLUID FLOW MACHINE

(71) We, ROLLS-ROYCE LIMITED, a British Company, of Moor Lane, Derby, Derbyshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns a fluid flow machine such, for example, as a gas turbine engine.

It is frequently necessary to provide a fluid flow machine with one or more struts which extends across an annular duct of the machine. Such a strut, however, may produce a non-uniform pressure distribution around the annular duct which can, for example, cause substantial stresses to be imparted to any rotor blades mounted in the duct and upstream of the strut.

According to the present invention, there is provided a fluid flow machine provided with an annular duct having therein a vane assembly comprising a row of angularly spaced-apart stator vanes and at least one strut which extends across the duct and which has at least a leading surface having a leading edge and a trailing edge, the stator vanes on opposite sides of the leading surface of the or each strut being axially staggered, said leading surface being, in operation, substantially parallel to the direction of flow thereover and said vane assembly being such that a substantially uniform pressure distribution is formed upstream thereof.

Preferably the or each strut and the stator vanes are helically arranged and form one substantially complete helical turn. The strut, or at least one of the struts may be disposed between the most upstream and the most downstream stator vane of the said substantially complete helical turn.

In one embodiment said blade assembly includes a respective wall member which with the or each strut defines a duct portion, the stator vanes in said duct portion being helically arranged, the most downstream stator vane being adjacent said leading surface. Thus the stator vanes disposed outside said duct portion may be circumferentially arranged.

The annular duct may be a fan duct of a gas turbine engine, the said stator vanes being outlet guide vanes of a fan mounted in said duct, and the or each said strut extending between the engine and fan casings. Thus the fan may be a front fan.

In another preferred embodiment said blade assembly includes a second row of angularly spaced-apart stator vanes disposed downstream of the first-mentioned row, the or each strut extending between said rows, said vane assembly being such that said trailing edge is disposed between said rows and the or each strut also has a trailing surface substantially downstream of said second second row, said trailing surface being substantially parallel to the direction of flow thereover. Thus the annular duct may be the main flow duct of a gas turbine engine, the or each strut forming part of bearing support structure which supports a main shaft of the engine from the engine casing, the said main shaft being disposed radially inwardly of the annular duct.

The invention is illustrated, merely by way of example, in the accompanying diagrammatic drawings, in which:—

Figure 1 shows a gas turbine front fan engine in accordance with the present invention,

Figure 2 is a broken-away view on a larger scale of part of the engine of Figure 1,

Figure 3 is a schematic plan view of the embodiment of Figures 1 and 2,

Figure 4 is a broken away sectional view of another gas turbine engine in accordance with the present invention,

Figure 5 is a developed part view looking in the direction of the arrow 5 of Figure 4, and

Figure 6 is a developed part view of another gas turbine engine according to the present invention.

In Figure 1 there is shown a front fan gas turbine engine 10 having an engine casing 11 within which are mounted a compressor,

combustion equipment, and a turbine (not shown) of the engine.

The said compressor and turbine are mounted drivingly on a rotor shaft 12 which is provided at its forward end with front fan rotor blades 13. The fan rotor blades 13 are disposed at the upstream end of an annular duct 14 which is defined between the engine casing 11 and a fan casing 15 which is arranged concentrically outwardly thereof.

The engine casing 11 is supported from the fan casing 15 by way of a strut (or "pylon") 16 which extends across the duct 14 and thus between the engine and fan casings 11, 15.

A helical row of angularly spaced apart, axially staggered aerofoil-shaped outlet guide vanes 17 is arranged in the duct 14 immediately downstream of the fan rotor blades 13. The strut 16 is arranged between the most upstream guide vane 20 and the most downstream guide vane 21 of the said helical row, so as to form one substantially complete helical turn therewith, the strut 16 having leading and trailing edges 22, 23 which are respectively disposed upstream and downstream of the leading edges 24, 25 of the guide vanes 20, 21. The strut 16 has, moreover, a leading surface 26 which is substantially parallel to the direction of flow thereover. Thus, as will be appreciated, the strut 16 is axially staggered with respect to the guide vanes 20, 21 which are disposed on angularly opposite sides thereof.

By reason of the arrangement of the strut 16 in the said helical row, an undesirable non-uniform pressure distribution is substantially avoided upstream of the strut. The required pylon leading edge 22 replaces the most upstream vane leading edge, and the initial portion 26 of the "suction surface" (i.e. the low-pressure side) of the pylon is quite straight and is placed at the local air inlet angle. The straight portion 26 of the suction surface is followed by a tight corner which simulates a vane suction surface and conforms with the tail end of the vane helix. The pylon then continues axially from the vane trailing edges on both the "pressure" (i.e. high pressure side) and suction surfaces. It is clear that the flow field does not differ in the surroundings of any two vanes and thus that the system will, ideally, give no upstream disturbance. Undesirable stresses are therefore not imparted to the rotor blades 13.

Figure 3 shows schematically the arrangement of Figures 1 and 2. The flow over the strut 16 is shown in thick lines. The helical row of guide vanes 17 subtends an angle θ to the diametral plane of the duct 14 and the inlet flow and outlet flow directions of the row of guide vanes subtend angles α_3 and α_4 respectively to the axial direction. The effective inlet width defined by the strut 16 is t^*, and t_o is the thickness of the strut.

If the length of the leading surface 26 is l, then when the leading surface 26 is substantially parallel to the direction of flow thereover:

$$l=\frac{t_o}{\operatorname{Sin}\beta} \qquad \text{and } \beta=\alpha_3-\alpha_4$$

$$\therefore \quad \frac{t_o}{l}=\operatorname{Sin}(\alpha_3-\alpha_4)$$

Similarly:

$$\frac{t^*}{l}=\operatorname{Sin}\alpha_3$$

Hence:

$$t^*=\frac{t_o \sin\alpha_3}{\operatorname{Sin}(\alpha_3-\alpha_4)} \qquad (1)$$

If C is the circumference of the duct 14 then:

$$\tan\theta=\frac{h}{(C-t^*)}$$

$$\therefore \quad \theta=\tan^{-1}\frac{t^*}{C-t^*(\tan\alpha_3)} \qquad (2)$$

Therefore for a given fan 13, the angle subtended to the diametral plane by the row of guide vanes 17 is defined by the expression (2) above. In effect, therefore, the guide vanes and the strut present an obstruction in the duct 14 which forms a uniform pressure distribution upstream thereof.

If a plurality of struts 16 are disposed in the duct 14 then expression (1) becomes:

$$t^*=\frac{\sum_{i=1}^{i=n} t_{o_i} \sin\alpha_3}{\operatorname{Sin}(\alpha_3-\alpha_4)}$$

where t_{o_i} = the thickness of the 'i'th strut, there being n struts altogether.

and, as before,

$$\tan\theta=\frac{t^*}{(C-t^*)\tan\alpha_3}$$

Thus as long as the row of guide vanes and the struts are arranged on a common helical row then the same expression applies for the

angle subtended to the diametral plane by the row of guide vanes 17 having a plurality of struts 16 as if there was only a single strut present.

In Figure 4 there is shown a gas turbine engine 30 having a main annular flow duct 31 which is disposed internally of an engine casing 32. The engine 30 has a main shaft 33 which is disposed radially inwardly of the duct 31 and which is supported from the engine casing 32 by bearing support structure 34.

The duct 31 has *inter alia*, mounted therein in flow series an intermediate pressure compressor 35, a row of outlet guide vanes 36, a row of inlet guide vanes 37, and a high pressure compressor 38, the portion of the duct 31 between the guide vanes 36—37 forming a "swan neck" duct portion 40. Through this duct portion 40 there extend a plurality of angularly spaced apart radial bearing members 41 which form part of the bearing support structure 34.

Each of the members 41 extends through a strut 42 (Figure 5) which extends across the duct 31 and which is axially staggered with respect to, and has an angularly opposite sides thereof, axially staggered angularly spaced apart stator vanes which may be constituted by the rows of vanes 36, 37 or may be additional thereto, these stator vanes producing a substantially uniform pressure distribution upstream of the struts 42 since they are helically arranged therewith as defined in relation to the embodiment shown in Fig. 2. Thus the blockage and turbulence otherwise produced in the duct portion 40 is reduced.

As will be seen from Figure 5, the stator vanes 36, 37 are respectively arranged on the trailing edge of the leading surface 43 and the leading edge of the trailing surface 49 of the struts 42, the leading surface 43 of each strut 42 being substantially parallel to the direction of flow thereover, as indicated by arrow 44. The flow from the vanes 36 onto edges 45, 46 of the struts 42 is substantially parallel thereto as indicated by arrows 47, 48 respectively. The trailing surface 49 of each strut 42 is substantially parallel to the outlet flow from the vanes 37 as indicated by the arrow 50.

It will be appreciated that the angle subtended to the diametral plane by the row of guide vanes 36 is preferably equal to that subtended by the guide vanes 37 but this is not essential and the two rows could subtend different angles to the diametral plane.

It is not necessary that all the guide vanes of the row need be arranged helically. Thus, as shown in Figure 6, a plurality of guide vanes 55 are arranged circumferentially or, in a diametral plane of, an annular fan duct 56. A strut 57 has a leading surface 58 whose direction is substantially parallel to the direction of flow as indicated by the arrow 59. The leading surface 58 defines with a wall member 60 a duct portion 61 which has therein a plurality (e.g. three) guide vanes 62 which are helically arranged at an angle to the diametral plane of the duct 56.

It will be appreciated that several struts 57 may be provided with duct 56 each strut having a respective wall member 60 and guide vanes 62. The guide vanes 55 between each strut being arranged on said diametral plane.

In order to ensure a uniform pressure distribution upstream of the vanes, the ratio of inlet area to outlet area for the helical portion of the row must be the same as that for the circumferential portion of the row. The area-correcting duct 61 is therefore provided by the addition of wall member 60 which is thin and substantially parallel to the surface 63 of the respective strut 57.

As will be appreciated the area compensation for the strut 57 is in the diametral plane but as an alternative the area compensation could be in the radial direction.

In all the embodiments of the invention it is desirable that the ratio of inlet area to outlet area for any adjacent pair of guide vanes or stator vanes is equal. Thus the guide vanes or stator vanes need not be equi-angularly spaced apart. The struts need not necessarily be provided for support purposes but may be provided just to produce a uniform pressure distribution upstream of a row of stator or guide vanes.

WHAT WE CLAIM IS:—

1. A fluid flow machine provided with an annular duct having therein a vane assembly comprising a row of angularly spaced-apart stator vanes and at least one strut which extends across the duct and which has at least a leading surface having a leading edge and a trailing edge, the stator vanes on opposite sides of the leading surface of the or each strut being axially staggered, said leading surface being, in operation, substantially parallel to the direction of flow thereover and said vane assembly being such that a substantially uniform pressure distribution is formed upstream thereof.

2. A fluid flow machine as claimed in claim 1 in which the or each strut and the stator vanes are helically arranged and form one substantially complete helical turn.

3. A fluid flow machine as claimed in claim 2 in which the strut, or at least one of the struts is disposed between the most upstream and the most downstream stator vanes of the said substantially complete helical turn.

4. A fluid flow machine a claimed in claim 1 in which said vane assembly includes a respective wall member which with the or each strut defines a duct portion, the stator vanes in said duct portion being helically

arranged, the most downstream stator vane being adjacent said leading surface.

5. A fluid flow machine as claimed in claim 4 in which the stator vanes disposed outside said duct portion are circumferentially disposed.

6. A fluid flow machine as claimed in any preceding claim in which the annular duct is a fan duct of a gas turbine engine, the said stator vanes being outlet guide vanes of a fan mounted in said duct, and the or each said strut extending between the engine and fan casings.

7. A fluid flow machine as claimed in claim 6 in which the fan is a front fan.

8. A fluid flow machine as claimed in claim 1 in which said vane assembly includes a second row of angularly spaced-apart stator vanes disposed down-stream of the first-mentioned row, the or each strut extending between said rows, said vane assembly being such that said trailing edge is disposed between said rows and the or each strut also has a trailing surface substantially downstream of said second row, said trailing surface being substantially parallel to the direction of flow thereover.

9. A fluid flow machine as claimed in claim 8 in which the annular duct is the main flow duct of a gas turbine engine, the or each said strut forming part of bearing support structure which supports a main shaft of the engine from an engine casing, the said main shaft being disposed radially inwardly of the annular duct.

10. A fluid flow machine substantially as herein described with reference to and as shown in the accompanying drawings.

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Fig. 1

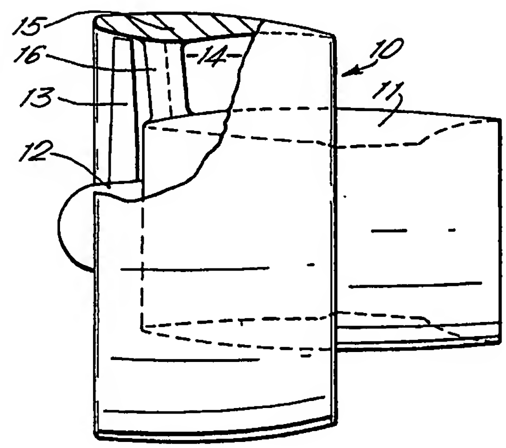
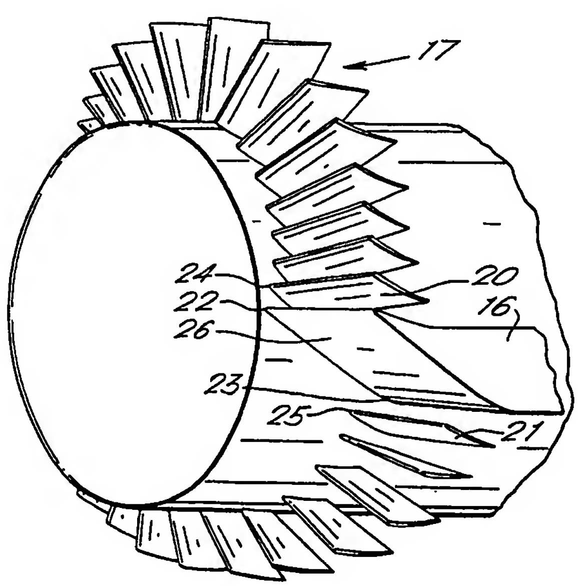


Fig. 2.



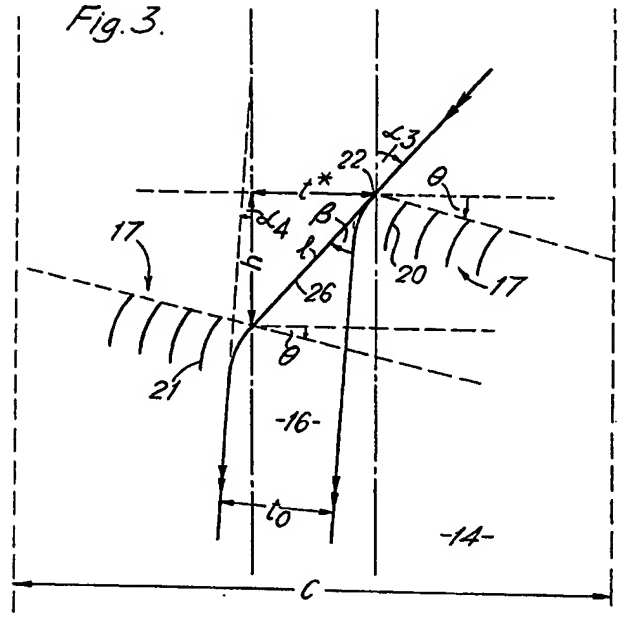


Fig. 3.
α3
22
θ
t*
β
α4
ℓ
h
17
26
20
17
21
θ
-16-
t0
-14-
C

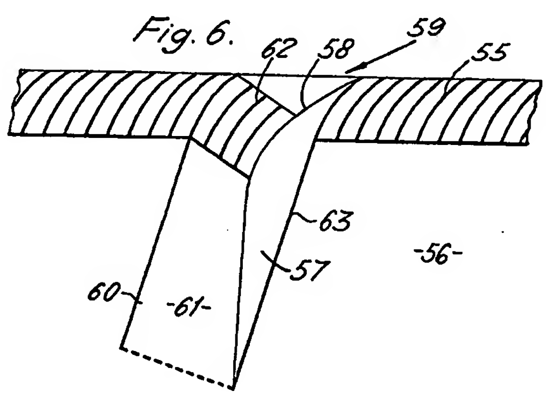


Fig. 6.
62
58
59
55
63
-56-
57
60
-61-

1,291,235 COMPLETE SPECIFICATION
3 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEET 3

Fig. 4.

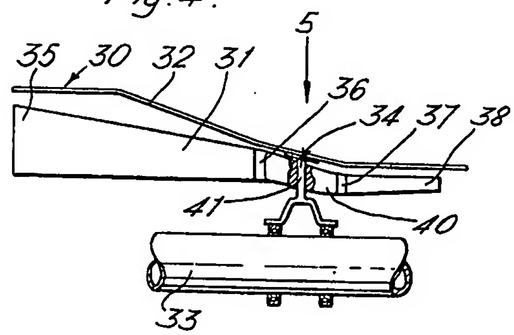


Fig. 5.